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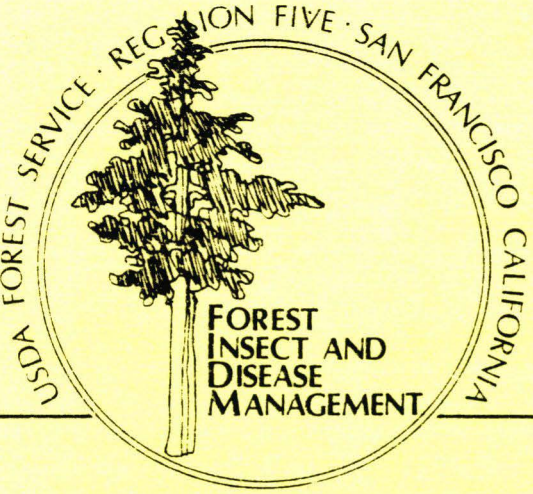


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# AN EVALUATION OF TREE MORTALITY IN LAGUNA MOUNTAIN RECREATION AREA CLEVELAND NATIONAL FOREST

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## INTRODUCTION

Laguna Mountain Recreation Area is a part of the Descanso Ranger District, Cleveland National Forest. It is a wooded plateau at 5200-6400 ft. elevation, 40 mi east of San Diego, California (Fig. 1). As the forested area most accessible to the inhabitants of San Diego and surrounding communities, it receives as many as 1.5 million visitor-days of use per year. Four campgrounds, two picnic areas, over 200 summer homes, and two institutional camps located on land administered by the Forest Service provide for the public's needs. The Forest plans to spend approximately eight million dollars in the next 15 years developing additional recreation facilities.

## VEGETATION

Laguna Mountain contains about 7100 acres of timber in the yellow pine type, dominated by Jeffrey pine (Pinus jeffreyi), Coulter pine (P. coulteri) and California black oak (Quercus kelloggii), with a minor component of canyon live oak (Q. chrysolepis) and incense-cedar (Calocedrus decurrens). Coast live oak (Q. agrifolia) can be found around the fringes of the plateau, and Parry pinyon (P. quadrifolia) occurs on the eastern, abrupt edge of the plateau.

## INSECTS AND DISEASES

Forest pests of Laguna Mountain have received considerable attention. Prior to about 1975, direct insect suppression measures aimed at reducing tree mortality caused by western pine beetle (Dendroctonus brevicomis) and California flatheaded borer (Melanophila californica) had been carried out for about fifty years. Surveys to locate western dwarf mistletoe (Arceuthobium campylopodum) show that this parasite is present over much of the forested area of the mountain, and is extremely heavy in localized areas (Fig. 2). Annosus root rot (Fomes annosus) has been noted since the early 1940's, and Laguna Mountain has the dubious distinction of containing the largest infection center so far discovered in California, about 6 acres in size.

In spite of past pest suppression efforts, observations indicate that tree mortality continues to occur at high levels on Laguna Mountain; and increases in recreation use, such as now being planned, are often accompanied by further deterioration of sensitive stands. In order to accomplish the

Southern California Timber Management Plan, which specifies that these forests will be managed for recreational, watershed, wildlife, and scenic resources, and at the same time will be maintained in a healthy condition, the Cleveland National Forest and FIDM, Pacific Southwest Region, jointly agreed to conduct a biological evaluation with the following three principal objectives.

- To determine the amount of pest-caused mortality occurring between spring of 1976 and spring of 1977 and characterize it by the stand factors and pest complexes involved.
- To determine the location of all root disease centers.
- To formulate integrated pest management strategies aimed at preventing/reducing tree mortality.

## METHODS

A modification of the Region 5 Pest Damage Inventory (PDI) was used to determine the levels, locations, and causes of tree mortality. The PDI uses aerial photos as a means of estimating levels of mortality, followed by the installation of ground plots at dead tree groups in order to determine stand and site factors and to identify associated pests.

All but 300 of the 7100 forested acres were photographed at a scale of 1:5000 using aerial color transparency film and at a scale of 1:10,000 using color negative film for prints. The areas not photographed, inadvertently were missed when the photography was flown. The color transparencies were interpreted for all conifer mortality which had occurred up to one year before the photographs were taken in April 1977 and that mortality was circled in red. District personnel agreed to restrict cutting and removal of dead trees for one year starting in April 1976 in order to allow an accurate estimate to be made. A random sample of 124 red-circled mortality groups identified on the photos was drawn and each group was visited on the ground to obtain the following information; stand aggregation type and basal area; number, size and species of dead trees; and the pest or combination of pests which were judged to have contributed to death.

The formula used for estimating number of dead trees was:

$$T = \frac{71}{68} \frac{N}{n} \left( \sum_{i=1}^{n} t_i \right)$$

Where T = estimated number of trees.

$\frac{71}{68}$ = $\frac{\text{Total possible acres of timber type}}{\text{Acres of timber type photographed}}$

N = number of mortality groups photo interpreted

n = number of mortality groups checked on ground

$t_i$ = number of trees in mortality group i

The formula used for estimating the standard error was:

$$S = \left(\frac{71}{68}\right)^2 N^2 \frac{\sum_{i=1}^{n} (t_i)^2 - \left(\sum_{i=1}^{n} t_i\right)^2 / n}{n(n-1)}$$

In addition, all areas which contained the following photo signatures indicating the presence of root diseases were outlined in blue on the photos, even when there was no current mortality present.

1) old stumps,

2) newer stumps,

3) stobs (broken off snags),

4) white snags (older),

5) black snags (newer),

6) current mortality (sorrel), and

7) thin-crowned or fading trees.

To be considered a F. annosus center, there had to be at least three of the above signatures present, or if there were just two, they had to be numerous or obvious. Also, the signatures had to be spatially related in a way that would indicate the spread of F. annosus from one tree to another. For instance, a snag located 100 feet from current mortality, with no signatures in between, was not considered evidence of the presence of root disease.

Ground checks of the 152 root disease centers found on the photos determined the accuracy of the interpretation and the identity of the causal agents involved.

## RESULTS

Table 1 summarizes the tree mortality by stand strata.[1/] The overall average for the one year period April 1976 to April 1977 was 0.645 trees per acre, or 0.31% of the stems. There was considerable variation in mortality rate between strata, ranging from a low of .020% of stems in the Phd 3 ≡ without understory to a high of 1.01% in the combination stratum Phd 3-, = without understory.

Table 2 shows the tree mortality by associated pest species. Three pests, California flatheaded borer, western dwarf mistletoe, and annosus root rot, were associated with 90% of the dead trees. These and other pests usually acted in pest complexes consisting of both insects and diseases.

Only 15% of the trees were found to have a single pest, and this estimate is probably high because some pests are difficult to detect with the diagnostic methods available. A combination of annosus root rot, western dwarf mistletoe, and California flatheaded borer killed more trees (18%) than any other complex, followed by flatheaded borer/dwarf mistletoe complex (15%), and root rot/flatheaded borer complex (11%).

Root disease centers were delineated regardless of whether they contained current mortality; 1383 centers were marked on the 1:5000 scale photos, approximately one center for every 5 acres of conifer type. The sample ground check of 152 centers indicated that 80% of the delineated trees did contain root diseases. On the other hand, 67 suspected centers, which because of a lack of sufficient numbered signatures were not delineated as centers on the photos, were ground checked; root diseases were found in nine, or 13%. The accuracy of the delineation is roughly $1383 \pm \frac{180}{277}$. Copies of the 1:5000 scale transparencies, with mortality located on them, are on file in the Remote Sensing Section of FIDM. Copies of the 1:10,000 scale photographs, showing root disease centers, are on file at Descanso Ranger District and at FIDM. A map of root disease centers (Fig. 3) was prepared from the photographs by Forest personnel with copies on file with the Forest Landscape Architect and with FIDM.

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[1/] A stand stratum is the combination of tree species, size and density which characterizes an area large enough, usually exceeding 10 acres, to distinguish it from other strata. For instance, the Phd 3 = stratum contains mainly pines with at least 20% hardwoods, young sawtimber-sized (DBH 11-22 in), with 80% crown cover.

TABLE 1. Mortality by Stand Strata.

| CONIFER STRATUM | STRATUM AREA (acres) | AVERAGE STEMS/A | DEAD TREES/A | DEAD TREES AS PERCENT OF STEMS/A |
|---|---|---|---|---|
| Phd 3-,= With understory | 3305 | 200 | 0.531±0.072* | 0.27 |
| Phd 3=, = With understory | 2207 | 285 | 0.764±0.110 | 0.27 |
| Phd 3-,= No understory | 185 | 100 | 1.150±0.193 | 1.01 |
| Phd 3= No understory | 560 | 160 | 0.323±0.206 | 0.20 |
| Phd 4 all | 570 | 50 | 0.192±0.021 | 0.38 |
| TOTALS | 6827 | 209 | 0.645±0.058 | 0.31 |

*Confidence intervals are based upon 1 standard error of the estimate.

TABLE 2. Pests Associated with Dead Trees.

| PESTS | DEAD TREES | % OF TOTAL DEAD TREES | DEAD TREES/A WITH PEST |
|---|---|---|---|
| California flatheaded borer (MC) | 2550 | 60.9 | 0.375 |
| Western dwarf mistletoe (AP) | 2533 | 60.6 | 0.373 |
| Annosus Root rot (FA) | 2006 | 48.0 | 0.300 |
| Elytroderma needlecast (ED) | 323 | 7.7 | 0.048 |
| Shoestring root rot (AM) | 221 | 5.3 | 0.033 |
| Red turpentine beetle (DV) | 204 | 4.9 | 0.030 |
| Unknown causes (UK) | 255 | 6.1 | 0.038 |

## DISCUSSION

The overall mortality rate on Laguna Mountain is much higher than that occurring in other parts of California, exclusive of drought years, according to surveys made using the same methods (Table 3). The only mortality rates higher than those found on Laguna Mountain occurred in northern California during and immediately after the 1976-1977 drought. A survey conducted on the San Bernardino National Forest from 1976 to 1978 indicated mortality rates far lower than those found on Laguna Mountain. These results can be used to formulate a prognosis for the mountain. Given a high mortality rate during a period of above normal precipitation (April 1976 to April 1977), the mortality rate can be expected to increase during and immediately following years of below normal precipitation. To state the problem simply, the trees on Laguna Mountain are unhealthy compared to other forested areas of the State, and future adverse environmental conditions might well be expected to contribute to an increase in the mortality rate.

Three major pests are responsible for almost all of the current mortality on Laguna Mountain. Annosus root rot and western dwarf mistletoe weaken trees which are then killed by the flatheaded borer.

Previous experience indicates that moisture-stressed trees or those under severe competition are often killed by flatheaded borers and bark beetles. The bark beetle and pine engraver beetles are not now contributing to appreciable mortality, but mortality attributable to these insects might well be expected to increase during periods of moisture stress.

The large numbers of dead trees killed by two or more pests are evidence that the successful reduction of these pest-caused losses will depend upon the integration of multiple pest management strategies and sound silvicultural procedures.

## BIOLOGY AND MANAGEMENT STRATEGIES

### DWARF MISTLETOE

Biology. Western dwarf mistletoe infects Jeffrey, ponderosa, and Coulter pines. Other conifers are rarely infected and hardwoods are immune. The plant is an obligate parasite, obtaining all of its nutrients, water, and minerals from the host tree. The mistletoe plants are a drain on the host tree. In pines they often cause the formation of "witches brooms" which divert nutrients from the rest of the trees. This results in the unbroomed portions of a tree being thin and off-colored, while the foliage of the brooms appear healthy, with long, bright-green needles.

TABLE 3. Mortality Rates in Various Parts of California, Using PDI Methods.

| YEAR | LOCATION | TREE MORTALITY/A |
|---|---|---|
| 1973 | Eldorado N.F. | 0.061±0.005 |
| 1974 | Stanislaus N.F. | 0.115±0.011 |
| 1976 | San Bernardino N.F. | 0.119±0.009 |
| 1977 | San Bernardino N.F. | 0.05 ±0.01 |
| 1977 | Northern California (Drought) | 0.714 |
| 1977 | Cleveland N.F. (Laguna Mt.) | 0.645±0.058 |
| 1978 | San Bernardino N.F. | 0.03 ±0.004 |
| 1978 | Northern California (Drought) | 0.921 |

Dwarf mistletoe spreads between trees and within the crowns of trees by means of small seeds which are forcibly ejected into the air. Spread from overstory to understory is limited to the distance traveled by the seeds, usually 20-60 feet, but as much as 100 feet if wind assists the seeds. A rule of thumb is that mistletoe can spread a distance equal to the height of the plants in the infected trees. Thus, large overstory trees can be a significant source of infection for an understory. Spread in even-aged stands is much less, averaging 1 to 2 ft per year. Dwarf mistletoe spreads upward in infected trees at a rate of about 4 inches/year. It has been suggested that trees with height growth of more than 4 inches per year will gradually outgrow the parasite, unless reinfected from nearby overstory trees.

Management Strategies. In developing stand management prescriptions for Jeffrey and Coulter pine stands infected with dwarf mistletoe, the following treatments or combinations of treatments may be used to control or lessen the impact of dwarf mistletoe on forest recreation stands. These suggested treatments are arranged by stand age class.

1) Even-aged (single-storied) stands above 6" dbh.

Thin mistletoe infected stands to maintain optimum growth of the residual trees and reduce stress. Select against mistletoe-infected trees. Consider the removal of all trees with a Hawksworth dwarf mistletoe rating of 5 and 6. (Such trees have a high probability of dying within the next 10 year period.) Treat all freshly cut stumps with borax to prevent invasion by F. annosus (see F. annosus control.)

Broom prune high-value dwarf mistletoe-infected trees if after removal of the dwarf mistletoe brooms, the tree will have live-crown ratios of 30% or more.

When treating stands, buffer strips should be considered at the margins of dwarf mistletoe infestations to prevent spread into or out of the treated area. These buffers should be used in the following order of priority.

a. Existing buffers (meadows, roads, and changes in type).

b. Type conversion, by removal of susceptible species.

c. Clear cut strips.

d. Periodic (2 year) pruning of strips of lightly infected pines.

Pruning of all infected branches in infected trees in an attempt to eradicate this pest is generally not recommended. But, in exceptional cases, when trees are especially valuable, pruning should be restricted to trees with a dwarf mistletoe rating of 1 or 2 which have infections only in the lower 1/3 of the crown. When pruning, remove all branches in the lower 1/2 of the crown. Do not attempt if this will result in a tree with a live crown ratio of less than 30% or if the tree will be exposed to continued infection from adjacent infected trees (Schedule 6 years resurvey and retreatment at 2 year intervals).

Eradication of small infestations of dwarf mistletoe patches in pole-sized to mature timber should be attempted only in areas of about 1 acre or less and these areas should be inspected and retreated every 2 years for a 6 year period.

2) Even-aged stands under 6" dbh.

Where infected overstory residuals threaten to infect young developing stands, remove the infected residual trees and prune and/or thin the mistletoe out of the infested understory. Plan for resurvey and retreatment of the young stand every 2 years for a 6 year period.

Young stands (seedling-sapling) moderately to heavily infected should be destroyed along with infected overstory trees within and at margins of the stand. Regenerate, resurvey, and retreat any new appearing infections along margins of treated area.

3) All-aged or multi-storied stands.

If regeneration of the stand is desired, the following steps should be taken in order:

a. Remove overstory.

b. Remove all infected trees from released understory.

c. Create a buffer strip around released stand, if needed.

d. Schedule post-treatment surveys every 2 years for 6 years.

If it is desirable to retain the overstory:

a. Remove infected understory in competition with overstory trees.

b. Broom prune highly valuable overstory trees.

c. Replant openings, as they develop with resistant species such as oaks or incense-cedar.

## ANNOSUS ROOT ROT

Almost all of the root disease centers identified on the mountain were caused by F. annosus. Although A. mellea was present and caused some damage, mortality due to this fungus is now low. This situation might change in the future if thinning and other management practices are applied to oaks. Armillaria mellea uses dead oaks, oak stumps or decadent live trees as a means of building up an energy base for attacking conifers; the creation of oak stumps as a result of stand management might increase the mortality due to this fungus. The following discussion will be restricted to annosus root rot, since it is now a major factor limiting stand management.

Biology. Fomes annosus, the cause of annosus root rot, is a pathogenic fungus closely related to the common wood decay fungi. It attacks a wide range of woody plants, causing both a decay of wood and a killing of sapwood and cambium.

The fungus spreads long distances by spores from conks which are usually produced in decayed stumps, under the bark of dead trees, or under the duff at the root collar of infected trees or stumps.

These spores drift through the air, upon landing on freshly cut pine stump surfaces or wounds in a live tree, germinate and colonize this new habitat. Once established in a stump or tree, the fungus grows through roots until it contacts the roots of adjacent trees. It then invades these new roots and grows through the new root system eventually killing this new host. In this way it passes from stump or dead trees to the roots of live trees and thence into other live trees in an enlarging circle or center. These centers usually continue to enlarge until they reach barriers such as openings or groups of non-susceptible plants.

Fomes annosus may remain alive in old infected roots or stumps for many years. Young conifers established within such centers often die shortly after their roots contact old infected roots in the soil.

Fomes annosus attacks most conifers. Resinous conifers, especially pines, are often killed quickly by cambial girdling before appreciable root decay occurs; but extensive decay can, on occasion, precede the death of pine. Coniferous species with non-resinous wood usually decay to a much greater extent before they die. The infection centers on Laguna Mountain contain resinous Jeffrey and Coulter pines and a small amount of non-resinous incense-cedar. Hardwoods are rarely damaged or killed by this pathogen in California and remain in or become established in centers in which conifers have been killed.

Because centers enlarge when the fungus spreads from root to root, the disease is most damaging in dense stands of susceptible trees where root contacts are frequent. Sparse stands or stands composed of susceptible and resistant trees are less subject to extensive damage. Stand age and tree size are important since roots of large trees extend for greater distances than roots of small trees and thus provide opportunities for spread between trees located farther apart.

Management Strategies. Annosus root rot is seldom controlled in the usual sense of the word; instead, new infections are prevented through the use of a chemical, and stands are manipulated so as to minimize the effects of the fungus. These and other measures designed to prevent hazards are:

Prevention of stump infection. Granular borax, sodium tetraborate decahydrate, is registered for application to freshly cut stumps. It is effective in preventing most new infections, and its application is required on all stumps cut in and near developed recreation sites (FSM R-5 Supp. 2305 and 2331.33). All of Laguna Mountain has been determined to be in or near developed recreation areas.

Type conversion. Conifers planted in and around infection centers will eventually become infected and die, leaving the center unstocked. All conifers are susceptible to one degree or another, but hardwoods are very rarely infected. Accordingly, hardwoods should be planted or otherwise regenerated in and around infected centers. The fungus will eventually die out in the centers so that conifers can once again be regenerated, but this will most likely take 50 years or more.

Location of facilities. Buildings, campgrounds, picnic areas, and other facilities should not be located near infection centers. Unfortunately, most potential building sites on the mountain are located near a center.

As an alternative, before locating important new developments, especially buildings, the Fomes annosus Location Map and the 1:10,000 scale photos should be consulted. When the root disease is indicated to be near proposed developments, and on-site

inspection should be made, preferably by a plant pathologist from FIDM, to advise on the root disease situation at the exact alternative locations for recreation developments. It is suggested that buildings not be located near the margins of centers containing large trees which will eventually die and may fall on these structures. On the other hand, they can be located well inside centers where the dangers of being hit by trees is minimal, and which will be regenerated after construction. In much the same way, roads and asphalt pads in campgrounds and parking lots can often be located in infection centers in order to take advantage of clearings which would otherwise have to be regenerated. Construction often causes additional infections due to tree scarring and root damage, and locating developments in existing centers will decrease the damage to the surrounding stand.

Removal of infected trees. Pines infected by annosus root rot usually are killed by bark beetles or borers, but sometimes an infected pine sustains extensive root decay and windthrows while still alive, causing property damage, personal injury or death. This type of tree failure occurs more frequently in incense-cedar than pine. It is recommended that a pathologist examine all centers near developments before construction begins so that all trees expressing root disease symptoms or other hazards can be removed. In addition, periodic inspections should be made after construction in order to identify additional trees so they can be removed. This inspection can be made by a FIDM pathologist or by a person assigned to the Forest but trained by FIDM.

Early, heavy thinning of young stands is recommended because it limits the number of successful stump infections and subsequent root disease centers. Small stumps under 8" in diameter and at least 12" high dry out quickly and the generous opening up of the canopy allows the sun to heat them to high temperatures lethal to the fungus.

## ELYTRODERMA NEEDLECAST

Elytroderma needlecast is present at a damaging level in only about 8% of the trees killed. However, this disease is concentrated in certain stands which are important for recreation purposes.

Biology. Elytroderma needlecast is caused by Elytroderma deformans, a fungus which infects ponderosa, Jeffrey and lodgepole pines. It is spread by means of spores dispersed from small fruiting bodies produced on infected needles. After initial infection of the current year's needles, Elytroderma becomes systemic in twigs. This perennial twig infection serves to reinfect each year's needles as they grow out and causes them to die and drop off the second year.

Infected twigs retain only the current year's needles. The systemic infections also produce "witches brooms" somewhat similar in appearance to the witches brooms produced by dwarf mistletoes.

Information on the effects of Elytroderma is sketchy, but it is believed that the fungus causes significant growth loss when it infects over 40% of the crown of pines. The impact of the large brooms is unknown. Elytroderma needlecast is often found around meadows and lakes and in swales, where presumably moisture and temperature is favorable for infection. This disease is found on Laguna Mountain mainly around Laguna Meadow and in the swale in Section 15 and 22, north and south of the "Big Curve" in the highway.

Management Strategies

Control. Control of this disease has been accomplished through manipulation of stand factors including removal of infected trees and favoring resistant species in areas prone to infection. Pruning of brooms may restore the vigor of weakened trees, as is the case with dwarf mistletoe brooms, but pruning cannot be recommended on an operational basis until it has been demonstrated to be effective.

CALIFORNIA FLATHEADED BORER

Biology. Hosts of the California flatheaded borer at Laguna Mountain are Jeffrey and Coulter pine. It is most severe in stands located on sites where environmental stress is common. Decadent or unhealthy trees are most frequently attacked, along with an occasional top of a thrifty, vigorous tree.

Eggs are laid in conical nitches cut in the outer bark. Newly hatched larvae penetrate directly through the bark to the phloem. Here the larvae may feed from a few months to 4 years without any apparent effect on the host tree. Should host vigor and larval abundance not allow them to succeed, the larvae cut very short galleries before they are killed. These galleries do not seriously injure the tree and are overgrown by the cambium. Should conditions be, or become, favorable for the larvae and unfavorable for the tree, the larvae develop rapidly and destroy the cambium.

Although this insect can kill trees weakened by dwarf mistletoe and root disease, its primary importance is rendering trees increasingly susceptible to bark beetles.

Management Strategies. See general discussion of insect control measures following the discussions of the biology of individual insect species.

## WESTERN PINE BEETLE

Biology. The western pine beetle breeds in ponderosa and Coulter pine. The beetle attacks the main stem of living trees and generally will not breed in slash, branches or trees less than 6 inches in diameter. There are several generations per year and some adult beetles probably are active in the Laguna Mountain area during most of the snow-free period.

Normally the western pine beetle breeds in trees which are stressed or in a state of low vigor because they are overmature or have been weakened by predisposing factors such as root rots, dwarf mistletoe, drought, overstocking and fire. This beetle has an aggregating pheromone which serves to attract other western pine beetles into the area of a tree under attack. Once the beetles are near the initial tree under attack, they may be able to overcome other healthy trees by their sheer numbers. The mass attack phenomenon in response to the release of the pheromone makes it possible for the death of one decadent or diseased Coulter pine to result in the death of several nearby healthy trees.

The western pine beetle frequently attacks a tree in conjunction with other beetles such as the California flatheaded borer, the red turpentine beetle, Dendroctonus valens, and pine engravers, Ips spp.

## JEFFREY PINE BEETLE

Biology. The Jeffrey pine beetle, Dendroctonus jeffreyi, occurs only in Jeffrey pine. Although it has never been reported on Laguna Mountain, the reasons for its absence are unknown so that discussion of this insect is included here for use if the situation changes. Jeffrey pine beetle normally breeds in scattered individual overmature or lightning-struck trees. Like the western pine beetle, the Jeffrey pine beetle has an aggregating pheromone which makes group kills a possibility. In general, group tree killing by this beetle is less common than with the western pine beetle and the groups are smaller. The Jeffrey pine beetle is less aggressive and its one-year life cycle makes a rapid population build up more difficult. Many of the trees attacked by the Jeffrey pine beetle have been previously attacked by flatheaded borers or pine engravers.

## RED TURPENTINE BEETLE

Biology. The red turpentine beetle normally attacks injured, weakened or dying Jeffrey or Coulter pines. Old age, root diseases, dwarf mistletoe, recent construction, soil compaction or injuries due to fire or other activity are frequently associated with attacks by this

beetle. Attacks are generally limited to the lower bole and each successful attack generally destroys less than a square foot of cambial area. If, however, these attacks are numerous enough to girdle the inner-bark, the tree will die. The number of attacks required to kill varies with the vigor of the host and cannot be predicted.

Successful attacks of the red turpentine beetle seldom occur in the absence of attacks by other bark beetles or the California flatheaded borer. Red turpentine beetle usually occurs with the increased stress on the host generated by the attacks of its associates although it may be a precurser to attacks by these other beetles. It is usually the combination of attacks that result in tree mortality.

## PINE ENGRAVER

Biology. Pine engraver beetles, Ips spp., are not listed in Table 2, because the survey methods used were not conducive to detecting these insects. Pine engravers are known to be present in the Laguna Mountain area and should be considered because they can seriously affect management plans.

Pine engravers will breed either in the tops of live pine trees or in fresh green slash. Attacks on live trees are usually limited to trees which are suppressed, or stressed by dwarf mistletoe, root disease, drought, fire, or the attack of other insects. If fresh slash is available in the spring, the pine engravers may build up in an area and cause locally heavy top killing by mid-summer. Attacks are made with the coming of warm weather in the spring. A new generation is produced in 6-8 weeks in the spring, to 4-6 weeks in mid-summer (August). Thus, several overlapping generations per year may be produced. The winter may be passed in any of the life stages of larvae, pupae, or adults, depending upon species involved.

Outbreaks in standing, healthy trees are sporadic and of short duration, and are often associated with some temporary stress or shock afflicting the host species, such as severe competition or sudden opening of the stand. Tree killing frequently occurs where green pine slash, which serves as breeding habitat, is left untreated during spring and summer.

Management Strategies. The insect complexes associated with tree mortality on Laguna Mountain are so interrelated that management strategies cannot be addressed to specific insects, but rather must be integrated in order to accomplish the expressed objective of maintaining a healthy forest.

The important insect species can be divided into those that are usually restricted to attacking predisposed and stressed trees, and those that are also capable of killing healthy trees by mass attack. The California flatheaded borer and the red turpentine beetles are examples of the former. The western pine beetle, pine engraver beetles and the Jeffrey pine beetle, where it is found, fall into the latter category, although the Jeffrey pine beetle is less aggressive than the western pine and pine engraver beetles. Management strategies are aimed at removing high risk Jeffrey and Coulter pines before they become a center of an outbreak, maintaining stocking levels which produce minimum stresses in trees, protection of individual trees, avoiding injuries to trees, and preventing the build up of pine engravers in slash.

Removal of High Risk Pines. High risk Jeffrey and Coulter pines can be recognized by their declining growth rate (lack of conical top), poor vigor (overmature or suppressed trees), dying tops and branches and short, sparse foliage. Trees with a dwarf mistletoe rating of 5 or 6, or trees on the edge of recognized root rot centers should be included in this category. The removal of high risk trees is important in managing of the western pine beetle and Jeffrey pine beetle because attacks by these beetles can result in killing of groups of trees. The purpose for removing high risk trees it to eliminate those trees most likely to become the center of bark beetle group kills before mortality occurs. If the tree in question is widely separated from other trees of the same species (perhaps 50 ft or more), this method of control is not appropriate because it is unlikely that group tree killing will occur.

Thinning. Thinning has been mentioned as a method for controlling dwarf mistletoe and it is also a method of preventing bark beetle-caused mortality. Thinning and weeding maintain optimal growth in the overstory so the trees are vigorous enough to successfully resist bark beetle attacks. The little experimental data available for California forests, all of it gathered from ponderosa pine, indicate that stands having basal areas in excess of 350 $ft^2$/acre on site I are more likely to sustain mortality than those with lower basal areas. Reducing the basal area to 100 $ft^2$/acre is probably appropriate for preventing mortality on Laguna Mountain, where the sites are poor because of a deficiency of water.

Chemical prophylaxis. Trees can be protected from attack by bark beetles by applying an insecticide to the bole. Although this technique is not 100% effective due to a number of variables, it offers a high degree of protection lasting from several months to a growing season. There are drawbacks to the use of preventative sprays; it is labor intensive work and consequently fairly expensive. Preventative sprays also require good ground access to the trees and they do not provide a long term solution to the problem. Preventative sprays do provide an alternative for special problems, such as the maintenance

of "character" trees, for which silvicultural methods are not feasible.

Avoiding damage to trees. The susceptibility of trees to attack by bark beetles is generally increased by tree injuries. Trees are often injured during forest operations, construction activities, and by recreational visitors. Many of these injuries can be prevented by an information and education program directed at Forest personnel likely to work in campgrounds and at recreational visitors and summer homes leaseholders.

Slash treatment for pine engravers. Pine engravers are the principle pest associated with residues in pine regions. Tree killing frequently occurs where green pine slash is used as breeding habitat during spring and summer. One approach to minimizing damage is to schedule slash-generation activities mostly in the late summer, fall and early winter, when the beetles are not flying or the slash has a high probability of drying out before the beetles can complete their development. Green pine slash created during the spring and summer should be treated to prevent the buildup of pine engraver populations. Because pine engravers can complete their development in about a month under ideal conditions, treatment should be carried out soon after cutting to be effective. Some methods of slash treatment that might be acceptable in dispersed recreation areas would include lopping and scattering slash in sunny areas to speed its drying out, crushing or mashing slash with logging equipment to make it unsuitable for pine engraver breeding or piling and burning the slash within a month of cutting. Broadcast burning the slash might work if it could be done while the slash was green and without damaging the residual stand. Another method which might work is to pile slash in a sunny area and tightly cover the pile with clear plastic. If the temperature under the bark of slash in all parts of the pile reaches 120°F, all brood currently in the pile will be killed. Lower temperatures will not be effective and where successful, this method will not prevent reinfestation of slash piles. The most acceptable methods of slash treatment in high use recreation areas would probably be disposal by chipping or removal from the site.

## APPLICATION OF INTEGRATED PEST MANAGEMENT STRATEGIES

The foundation of integrated pest management is sound stand management. Good stand management practices which are also effective pest management practices include (1) thinning to remove high risk and diseased trees and maintain vigor, health, and resistance of the leave trees, and (2) manipulation of stand composition and structure. The latter ensures that a variety of tree species and age classes with differing pest problems and susceptibilities are present, thus reducing the probability of the occurrence of an epidemic. These and other management practices are combined with control measures aimed at

reducing losses from all pests, present or probable. The degree to which management practices and control measures directed at a specific pest are successful is often affected by other pests which are present or which become established as a result of the management practice used. For instance, pruning of dwarf mistletoe brooms reduces stresses in Coulter and Jeffrey pines therein decreasing the probability of successful attacks by bark beetles, engravers and flatheaded borers. If however, a pruned tree is located on the margin of a root disease center, pruning may be of limited value at best, or a complete waste of time and money at worst, because the root disease fungus may predispose it to attack by cambium feeding insects. In the same way, thinning to maintain vigor, if done at the wrong time of year with inadequate slash disposal measures, can allow the buildup of slash breeding insects which can attack the remaining crop trees. Pest management strategies must be integrated with one another and with the total resource management plan if the objectives of the management plan are to be met.

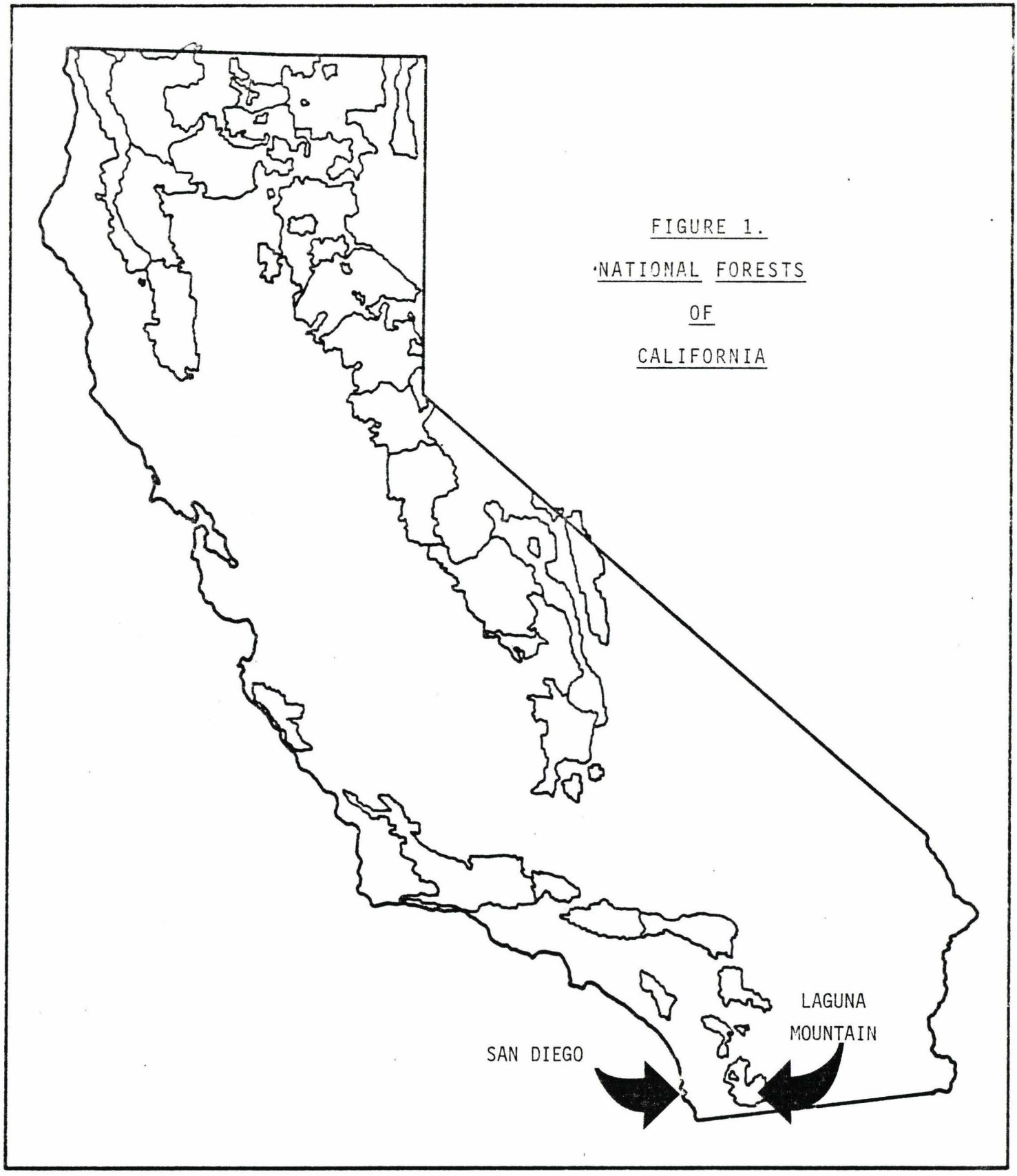


FIGURE 1.

NATIONAL FORESTS

OF

CALIFORNIA

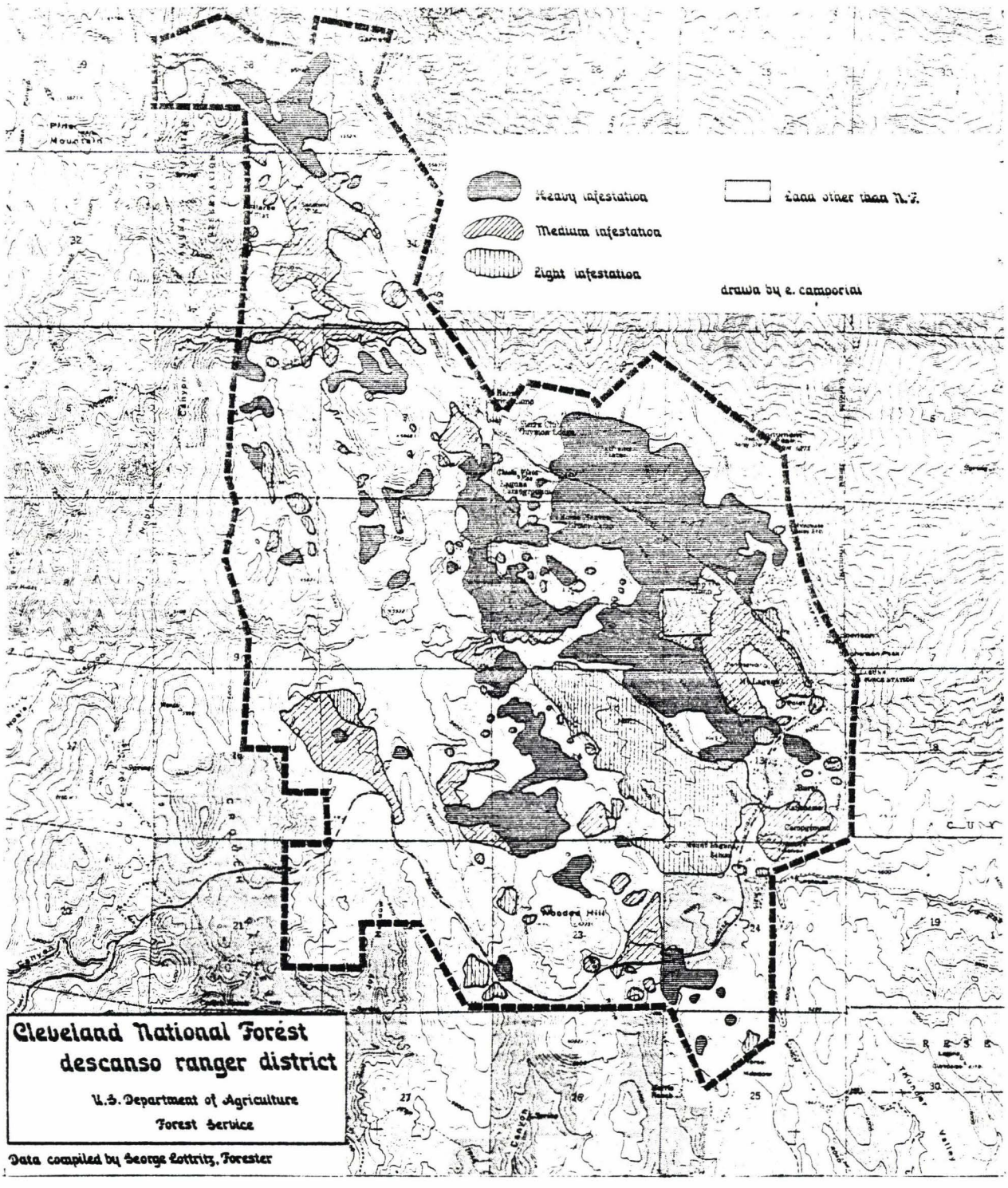


FIGURE 2. Location of dwarf mistletoe infestation on Laguna Mountain Recreation Area.

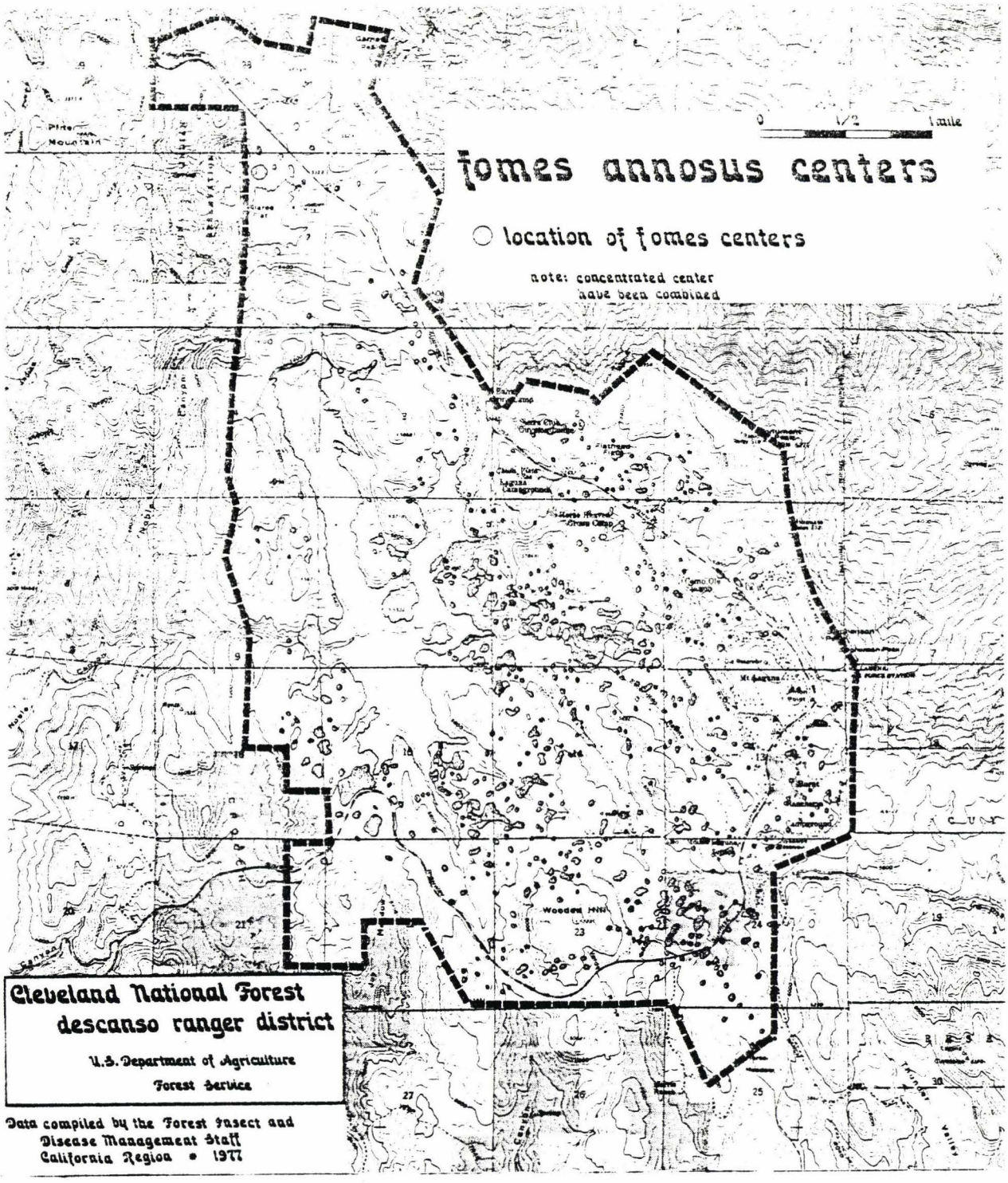
0 1/2 1 mile
fomes annosus centers
location of fomes centers
note: concentrated center have been combined
Cleveland National Forest
descanso ranger district
U.S. Department of Agriculture
Forest Service
Data compiled by the Forest Insect and Disease Management Staff
California Region • 1977

FIGURE 3. Location and distribution of Fomes annosus infection centers on Laguna Mountain Recreation Area.